

FIG. 1.— Completeness functions for each cluster field showing the fraction of recovered sources versus their input magnitude. For each cluster, 1000 generated galaxies were randomly distributed in 0.5 magnitude bins in a  $1.5 \times 1.5 \text{ Mpc}^2$  box centered near the cluster core. Sources that were extracted with magnitudes brighter than their input value were rejected as blendings. The 3.6 and  $4.5 \mu\text{m}$  channels exhibit a more gradual decline in completeness due to source confusion from greater crowding (see Barmby et al. 2008) which increases the likelihood of blendings.

and 21 mag in  $B$  and  $R$  respectively. Spectroscopy for the Coma cluster was taken as part of the Cluster and Infall Nearby Survey (CAIRNS: Rines et al. 2003). Galaxies targeted in this survey were selected from digitized images of the POSS I 103aE (red) plates which are complete down to  $E=15-16$ .

- *Abell 1689*: Data for Abell 1689 (Duc et al. 2002) were taken as follow-up to the photometric observations conducted by Dye et al. (2001). Photometry was acquired for the  $BVR$  bands and is complete to 23.0, 22.7 and 22.7 mag respectively. Spectra were obtained for most ( $\sim 75\%$ ) of the photometric cluster members at  $R \leq 17.75$  mag which drops to  $\sim 40\%$  at  $R \leq 19.5$  mag.
- *MS 1358+62*: Observations of MS 1358 taken from Fisher et al. (1998) including photometry in the  $V$  and  $R$  bands and spectroscopy. Spectroscopic completeness was determined to be  $>80\%$  at  $R \leq 21$  mag when compared to photometric observations which were complete to  $R \sim 23.5$  mag.
- *CL 0024+17 and MS 0451-03*: Data for CL 0024 and MS 0451, including photometry from the HST WFPC2 instrument, are discussed in detail in Treu et al. (2003) and Moran et al. (2005, 2007). Photometry was measured to be complete to  $I \sim 25$  (Vega mags)<sup>2</sup> for CL 0024 and spectroscopic completeness was found to be  $> 65\%$  at  $I < 21.1$  and  $I < 22.0$  mag for CL 0024 and MS 0451 respectively. Additional ground-based photometry was also obtained in the  $BVR IJK_s$  bands reaching  $3\sigma$  depths of 27.8, 26.9, 26.6, 25.9, 21.6 & 19.7 mag for CL 0024 and 28.1, 27.0, 27.3, 25.9, & 20.2 mag for MS 0451 (Moran et al. 2007b).
- *MS 2053-04 and MS 1054-03*: Spectroscopy for MS 2053 is detailed in Tran et al. (2005a) and completeness determinations were assessed according to sampling and success rates. The success rate is defined

<sup>2</sup> Here the  $I$ -band refers to the F814W filter from the WFPC2 instrument



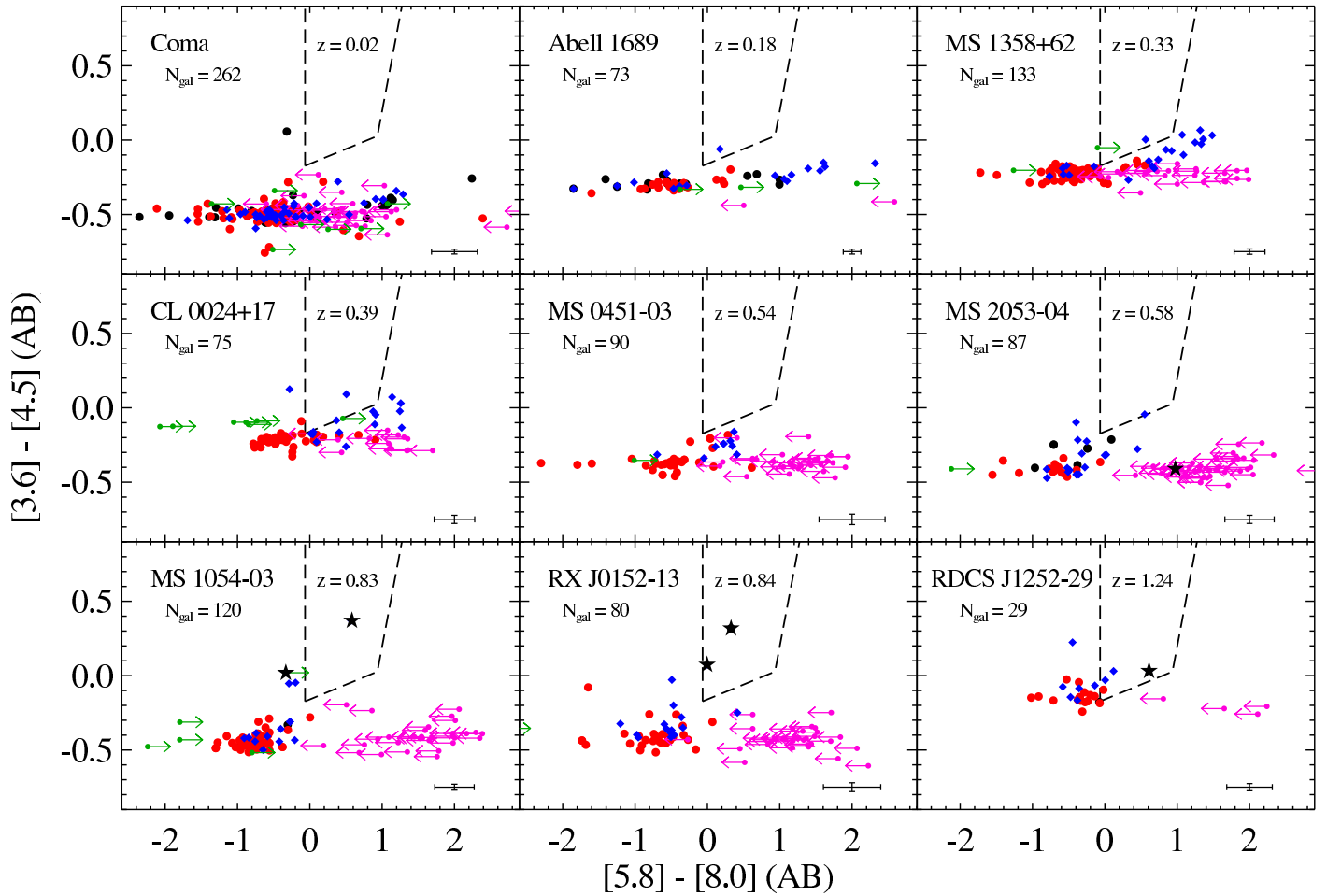


FIG. 3.— IRAC color-color plots used to select active galactic nuclei (IR-AGN; Stern et al. 2005) for the galaxy clusters in our study. Cluster redshift and number of confirmed members are shown in each panel. Data points correspond to morphologically classified early-type members (red circles), late-types (blue diamonds) and unclassified/mergers (black circles). Upper limits are determined for galaxies lacking detections in a particular channel (green and pink arrows, see §3). X-ray sources are indicated as stars. Mean uncertainties are shown in the lower-right corner of each panel. Early-type galaxies with blue IRAC colors populate the lower-left region in each plot (the “passive cloud”) whereas IR-AGN populate the area enclosed by the dashed lines. Our cluster IR-AGN are predominantly hosted by late-type galaxies.

for the Lacy and Stern criteria respectively. In Figure 2, the green diamonds in the Stern plot correspond to sources that are selected as AGN using the Lacy criteria, whereas cyan squares in the Lacy plot correspond to sources that are selected as AGN using the Stern criteria. Approximately 89% of the Stern-selected AGN are Lacy-selected AGN; however, the reverse shows that only  $\sim 33\%$  of all Lacy-selected AGN are also selected based on the Stern criteria. The higher IR-AGN fraction measured using the Lacy criteria is not surprising given that the track for M82 falls in the Lacy wedge. Because the Lacy criteria do not exclude starburst galaxies as effectively as the Stern criteria, we adopt the Stern criteria throughout the rest of this paper.

### 3.2. Individual Clusters

IRAC color plots for the nine massive galaxy clusters are shown in Figure 3. Only galaxies that have been spectroscopically confirmed as members with  $\geq 3\sigma$  detections in at least 3 IRAC channels are shown. Data points indicate morphologically classified elliptical/S0 galaxies (red circles), late-type galaxies (blue diamonds), unclassified/merger (black circles), sources with no detection in channel 4 only (pink arrows) and no detection in channel 3 only (green arrows). For sources that lacked detections in a

single bandpass, upper/lower limits were determined by assuming the 80% completeness magnitude for the respective bandpass (Table 2). Applying these limits mostly reveals a fainter population of passive galaxies. Considering that channels 1 & 2 (shorter wavelength) probe to fainter magnitudes than channels 3 & 4 (longer wavelength), galaxies in the “passive cloud” (with declining mid-IR SEDs) tend not to be detected at longer wavelengths while galaxies with IR-AGN (with increasing mid-IR spectra) are more likely to be detected in all four channels. This is why no potential candidate AGN are identified by our limit determinations. We use optically-determined coordinates for cluster galaxies to locate their IRAC counterparts. Using a matching radius of  $2''$  ( $6''$  for Coma) we find the rate of detecting a false positive to be  $< 1\%$ .

#### 3.2.1. Coma

The Coma cluster is one of the richest and most closely studied galaxy clusters and is known to be dominated by passively evolving systems with early-type morphologies (Michard & Andreon 2008). IRAC imaging for this cluster in all four channels covers roughly a  $51.1' \times 62.5'$  region centered on NGC 4874, a field of view that includes 348 spectroscopically confirmed cluster galaxies from the CAIRNS (Rines et al. 2003). Determining photometry with *Spitzer*



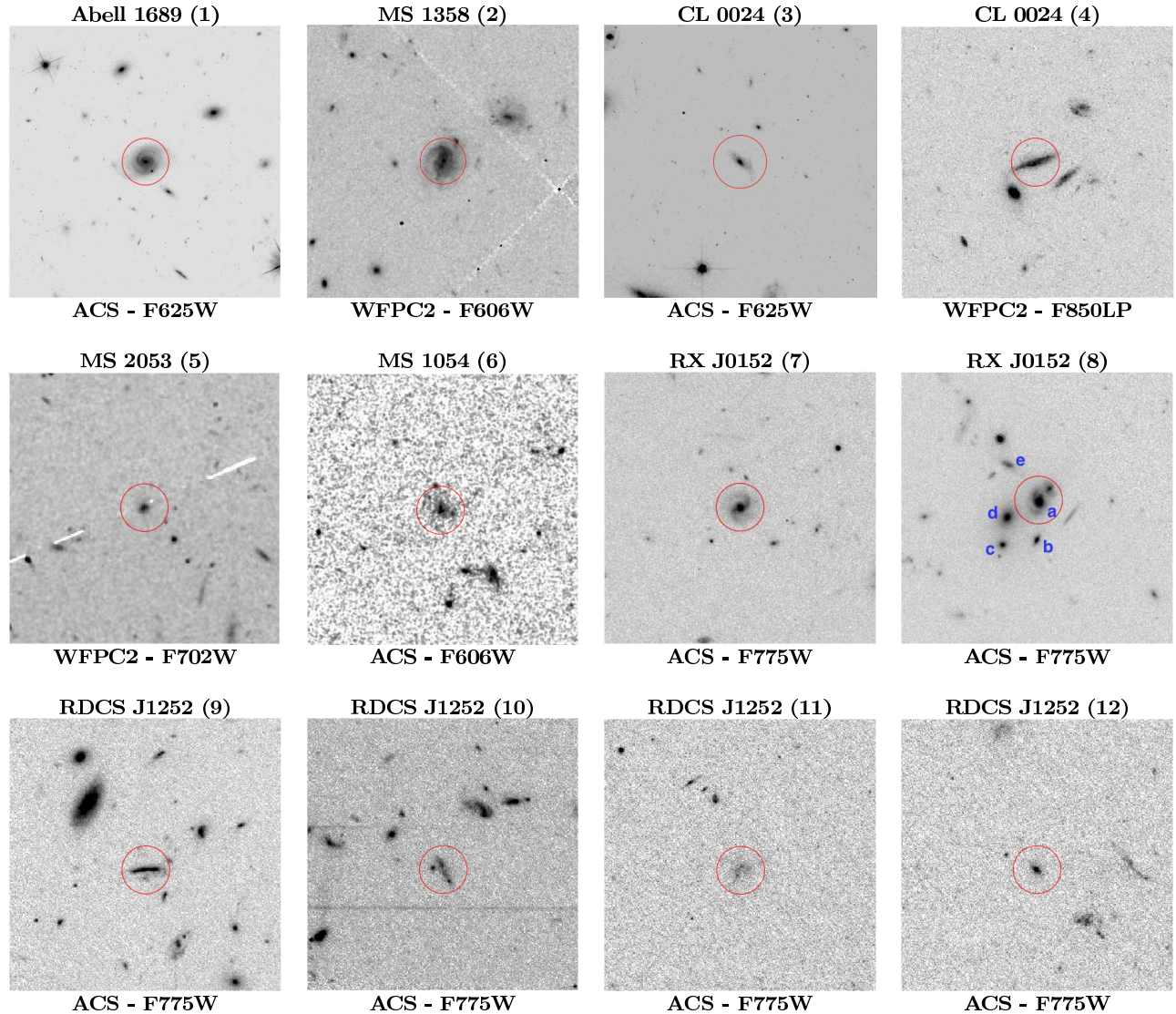


FIG. 4.— Thumbnails of our sample of infrared-selected AGN; images are from the *Hubble Space Telescope*. Numbers in parentheses correspond to the ID from Table 3. All images are  $\sim 150 \times 150$  kpc and are oriented North-up, East-left. Red circles correspond to the aperture of constant size ( $r \approx 12.6$  kpc) used to perform photometry on the IRAC images. See §3.2.8 for an explanation of the labels in panel 8.

which has a  $[3.6] - [4.5]$  color that is bluer than the IR-AGN selection region (Figure 3).

### 3.2.7. MS 1054-03

Spectroscopically confirmed members and photometry are taken from Tran et al. (2007). One cluster X-ray source was not included in the photometric catalog, but optical and X-ray data for this galaxy are available from Martel et al. (2007). Weak-lensing and X-ray analyses of MS 1054 show a clumpy nature to the dark matter and ICM profiles (Jee et al. 2005b). The presence of such substructure indicates that the cluster experienced a merger and has yet to fully virialized.

Earlier studies of MS 1054 reveal that it contains two members hosting X-ray AGN (Johnson et al. 2003) and 8 radio sources that can be powered by AGN or star formation (Best et al. 2002). We find only one infrared AGN at a distance  $\gtrsim 1$  Mpc from the cluster center that is also detected as both an X-ray and radio source. The second X-ray source lies near the edge of the IRAC footprints and is not detected at  $5.8\mu\text{m}$ . Though this does not allow it to

be identified as IR-AGN, it is not ruled out based on its  $[3.6] - [4.5]$  color (Figure 3).

### 3.2.8. RX J0152-13

Spectroscopic membership of cluster galaxies is from Demarco et al. (2005) and photometry from Blakeslee et al. (2006). This cluster shows signs of having gone through a large-scale merger event recently as indicated by its X-ray emission, luminosity distribution and weak-lensing profile (Jee et al. 2005a).

We detect two IR-AGN in this cluster, both of which are classified as X-ray QSOs (Martel et al. 2007); no other cluster galaxies are detected as X-ray sources. One of the IR+X-ray AGN is about 800 kpc from the cluster core while the second appears to be in a merging system. The latter detection is associated with five cluster galaxies within a projected radius of 30 kpc (Figure 4, neighboring cluster galaxies are labeled). Due to their proximity and the IRAC PSF, these galaxies are blended into one mid-IR source where galaxy *a* is the closest ( $\sim 0.7''$ ) to the centroid of the mid-IR emission. Redshifts in this quintet











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